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ON A NEW VARIETY OF HORNBLENDE.

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THE abnormal etching characters of the Philipstad hornblende referred to in the foregoing paper have suggested further study of the mineral; the description of its other properties shows that it should be regarded as an independent member of the amphibole group.

It is a variety given me for study by Professor Berwerth of the Royal Museum in Vienna. It is catalogued in that collection as "A. o. 458, Philipstad, Sweden." In addition to the original cleavage pieces for etching purposes, Professor Berwerth has been kind enough to turn over to me several fine crystals from the parent druse and enough extra material to permit of chemical analysis. To him, in thus abundantly supplying me with the mineral, my best thanks are due.

The crystals stand upon a compact mass of the same hornblende. The usual planes (110), (010), (100), (130), (011), (Tschermak's orientation), with normal interfacial angles, are well developed. The adjoining table shows the close correspondence of the observed angles with the calculated angles (cf. Lacroix, *Minéralogie de la France*) :—

	Observed.	Calculated.
110 : 130	150° 9'	150° 6'
010 : 130	147° 23'	147° 29'
110 : 110 (faces)	124° 11'—124° 17'	124° 11'
" " (cleavages)	124° 27'	
110 : 010	117° 50'	117° 54'
110 : 011	68° 33'	68° 46'
011 : 011	149° 12'	149° 11'

The unit prism is usually striated, owing to the presence of vicinal planes.

The reflexes in the goniometer from the planes of the vertical zone were often considerably displaced. This is probably due to the warping of the crystals. In several of the latter, it is possible to see with the

naked eye a marked flexure and even twisting of the prism-faces. I consider that the curious distortion of the etch-figures on (110) is due to the warping and consequent molecular strain.*

Several of the crystals are twinned parallel to (100).

The different etching behavior of the crystal-face and of the surface of cleavage has been explained as due to the zonal structure which is a prominent characteristic of the mineral. Six oriented sections and numerous cleavage pieces display the structure: it is illustrated in Figures 1, 2, and 3.

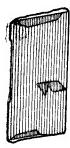


FIGURE 1.



FIGURE 2.



FIGURE 3.

FIGURES 1 AND 2.—Two sections parallel to (010) of the same doubly terminated crystal, showing zonal structure. In Figure 1 three zones, in Figure 2 four zones, are indicated. The zone of deepest tint is the most closely shaded, that of the lightest tint is left unshaded. The lines of shading run parallel to the cleavage trace. The trace of the edge 010 : 011 slopes downward from right to left.

FIGURE 3.—A section parallel to (110), showing three zones represented as in Figures 1 and 2. The extinction of the lightest zone is 17° , that of the intermediate zone is 19° , and that of the darkest zone is $22^\circ 30'$.

That this structure is rare in the amphiboles is clear from the recent statement by Becke in his essay on the zonal structure of crystals in the eruptive rocks.† Brögger describes one case in connection with his catophorite series. He notes the fact that sometimes the core of a crystal may consist of catophorite and the outer zone of arfvedsonite.‡ Tschermak long ago noted another example in a Vesuvius hornblende.§ Palache has figured the structure in crossite.||

The diagrams show that the bulk of each crystal is composed of pretty uniform substance, in which a darker colored phase of the mineral may be apparent, either without definite arrangement with respect to the former or in the form of true hour-glass intergrowth with it. In the

* See These Proceedings, Vol. XXXIV, page 400.

† Min. und petrog. Mittheilungen, 1898, Bd. XVII. p. 101.

‡ Die Gesteine der Grorudit-Tinguait-Serie, pp. 27 *et seq.*

§ Min. und petrog. Mittheilungen, 1871, Heft I. p. 40.

|| Bulletin, Department of Geology, Univ. of California, Vol. I. p. 187.

latter case, the darker areas of the section generally occur at the ends of the crystal, representing a late stage of growth, and are, with the rest of the crystal, commonly covered with a thin mantle of still a third kind of substance considerably lighter in tone than either of the other two.

Accurate sections cut in the appropriate directions by M. Werlein of Paris enabled me to determine the chief optical properties of the hornblende. The optical plane is parallel to the plane of symmetry. The axis of least elasticity lies in the obtuse angle β (Tschermak's orientation), making an angle of $15^\circ 9'$ with the vertical axis using yellow light or $15^\circ 5'$ using white light. The mineral is negative. In oil with an index of refraction of 1.609, I found the optical angle ($2H$) to be $53^\circ 24'$; in another oil with an index of refraction of 1.5011, I determined $2H$ to be $57^\circ 24'$. The hyperbolæ were not well defined, and, on account of strong absorption, the readings had to be made in the brightest white light procurable.

Owing to the extreme ease with which the mineral cleaves, it was found impossible to cut oriented prisms for the purpose of finding the indices of refraction; nor was any other method feasible under the circumstances. The true optical angle cannot then be found from $2H$, since the mean index of refraction is not known. It may, however, be considered that this index lies within the limits of 1.622 (tremolite) and 1.725 (hornblende, a high value). The first reading for $2H$ ($53^\circ 24'$) would give for $b = 1.622$, $2V = 52^\circ 56'$, and for $b = 1.725$, $2V = 49^\circ 42'$. The second reading ($57^\circ 24'$) would give for the same values of b , $2V = 52^\circ 46'$ and $49^\circ 24'$. The closeness of the agreement in the respective calculated values of $2V$ is rather fortuitous. The optical angle for this section is, then, within a degree or so of 50° .

The double refraction seems to be low. The dispersion is weak ($\rho < v$).

On (110) the extinction varies with the zones, increasing with the depth of tint. One dark zone gave in white light an average reading of $20^\circ 53'$; other lighter zones afforded extinction angles as low as 17° . The total range, so far as observed, lies between $22^\circ 30'$ and 17° . This can only mean that the optical angle for the different zones varies and must have values between 42° and 60° . (See Figure 3.)

The pleochroism is very strong in characteristic colors:—

a = light brownish green.

b = dark yellow green.

c = dark blue green.

$b > c > a$

This scheme of color and absorption applies to all the zones, the colors being simply modified in intensity.

The specific gravity was determined in methyl iodide solution at 16° C. The average for two unaltered crystals is 3.275. An outer light-colored zone gave 3.195, and an inner darker zone 3.230. The difference between the last two was too small to permit of the separation of the light and dark zones. I doubt that the lightest zone is more than one per cent of the whole. There are no important inclusions in the mineral.

M. Pisani of Paris made an analysis of the hornblende; it resulted as follows:—

SiO ₂	45.20
TiO ₂	0.84
Al ₂ O ₃	7.34
Fe ₂ O ₃	7.55
FeO	15.80
MnO	1.52
CaO	12.30
MgO	8.40
Na ₂ O	0.80
K ₂ O	0.37
Loss on ignition	0.70
	100.82

The analysis does not lend itself to calculation in a satisfactory way. There is considerable divergence in the proportions of the oxides from an old analysis by Rammelsberg of a Philipstad hornblende with a specific gravity suggestively close to that of our hornblende.*

It will be seen that the most noteworthy feature of the analysis is the high percentage of ferrous iron, a fact which correlates the mineral with hastingsite, which also has an unusually great proportion of this oxide, as well as an extraordinarily small optical angle.†

That a high content of ferrous iron (plus MnO) always means a correspondingly small optical angle cannot be asserted; pargasite affords a case sufficiently clear to invalidate any such claim. Yet it does seem that there is some intimate relationship between the amount of the oxide and the optical angle. The analogy of another group of allied silicates is in striking corroboration of this conclusion. Thus Hintze ‡ gives a table

* See Hintze, Handbuch der Mineralogie, 1894, p. 1223.

† Cf. Adams, Canadian Record of Science, 1896, Vol. VII. p. 77.

‡ Handbuch, p. 964.

of fourteen chemical and optical analyses of enstatite wherein the optical angle in oil continuously decreases from $133^{\circ} 8'$ (red light) to $59^{\circ} 20'$ (green light) while the percentage of (FeO plus MnO) simultaneously increases from 2.76% to 33.6%.

This hornblende is thus unique among the species yet described in that it possesses the combination of properties including an unusually small optical angle, an unusual pleochroism and absorption scheme, a well developed zonal structure, and quite anomalous etch-figures with hydrofluoric acid on the prism (110) and on the clinopinacoid.

For convenience of reference, this variety of amphibole may be called philipstadite, from the name of the locality whence it was derived.